Aerosol anthropogenic component estimated from satellite data

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[1] Satellite instruments do not measure the aerosol chemical composition needed to discriminate anthropogenic from natural aerosol components. However the ability of new satellite instruments to distinguish fine (submicron) from coarse (supermicron) aerosols over the oceans, serves as a signature of the anthropogenic component and can be used to estimate the fraction of anthropogenic aerosols with an uncertainty of ±30%. Application to two years of global MODIS data shows that 21 ± 7% of the aerosol optical thickness over the oceans has an anthropogenic origin. We found that three chemical transport models, used for global estimates of the aerosol forcing of climate, calculate a global average anthropogenic optical thickness over the ocean between 0.030 and 0.036, in line with the present MODIS assessment of 0.033. This increases our confidence in model assessments of the aerosol direct forcing of climate. The MODIS estimated aerosol forcing over cloud free oceans is therefore -1.4 ± 0.4 W/m^2.
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1. Introduction

[2] Climate change research [*Intergovernmental Panel on Climate Change* (*IPCC*), 2001] and studies of the aerosol forcing on the hydrological cycle [*Ramanathan et al.*, 2001] require knowledge of the anthropogenic component of the aerosol. Natural aerosols can cause variability in the climate system and be part of its feedbacks mechanisms, e.g. larger amount of dust generated during drought conditions in the Sahel [*Prospero and Lamb*, 2003] can cause cooling of the earth system and changes in the drought conditions. Only anthropogenic aerosol can be considered as an external cause of climate change [*Charlson et al.*, 1992]. Aerosol exerts a radiative forcing of climate via direct absorption and reflection of sunlight to space and via induced changes in the cloud microphysics, water content, and coverage [*Gunn and Phillips*, 1957; *Twomey et al.*, 1984; *Albrecht*, 1989; *Rosenfeld*, 2000; *Koren et al.*, 2004].

[3] Yet assessments of the aerosol radiative forcing [*IPCC*, 2001] are based only on models since we do not have a method to measure the amount and distribution of anthropogenic aerosol around the Earth. Previously [*Kaufman et al.*, 2002] we suggested that satellite data that distinguish fine from coarse aerosols can be used for this purpose. The reason is that natural and anthropogenic aerosols have different proportions of fine and coarse aerosols. Urban/industrial pollution and smoke from vegetation burning (mostly anthropogenic) have mostly fine aerosol, while dust and marine aerosols (mostly natural) are dominated by coarse aerosol but with significant fine aerosol fraction [*Tanré et al.*, 2001; *Kaufman et al.*, 2001].

[4] Here we use MODIS measurements over the oceans of the aerosol optical thickness and the fraction of the optical thickness contributed by fine aerosol [*Tanré et al.*, 1997; *Remer et al.*, 2005], to derive the anthropogenic optical thickness. The results are used to evaluate chemical transport models that are used to assess the aerosol forcing of climate.

2. Analysis

[5] The method for satellite based estimate of the aerosol anthropogenic component is based on the following assumptions:

[6] 1) The fraction of the aerosol optical thickness contributed by the fine aerosol is constant for a given aerosol type; e.g. fine aerosol dominates the optical properties for smoke and pollution and coarse aerosol dominates dust and maritime aerosol.

[7] 2) All smoke is from anthropogenic origin and all dust is natural. It is estimated that about 20% of biomass burning originates from wild fires [*Hobbs et al.*, 1997]. About 10% of the dust can be from anthropogenic sources [*Tegen et al.*, 2004]. We shall account for the smoke overestimate but not dust later in the paper.

[8] 3) MODIS derivation of the fine fraction is consistent: any errors in the derivation of the fine fraction are constant and the correlation with the true fine fraction is very good.

[9] 4) Based on AERONET and MODIS analysis [*Kaufman et al.*, 2001, 2005] it is assumed that the baseline marine aerosol optical thickness is 0.06 ± 0.01. This is the average marine optical thickness for calm conditions. Strong winds can elevate the sea salt concentration.

[10] We represent the total aerosol optical thickness τ_{550} by its anthropogenic (air pollution and smoke aerosol) - τ_{anth}, dust - τ_{dust}, and baseline marine - τ_{mar}, components:

$$\tau_{550} = \tau_{anth} + \tau_{dust} + \tau_{mar} \qquad (1)$$

The fine aerosol optical thickness, τ_f, measured by the satellite can be described as:

$$\tau_f = f_{550}\tau_{550} = f_{anth}\tau_{anth} + f_{dust}\tau_{dust} + f_{mar}\tau_{mar} \qquad (2)$$

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